28. A surface processing apparatus as claimed in claim 27, wherein said gas-diffusion concave has a depth in a range of 50 to 1,000 μm.

IN THE ABSTRACT

Please change the abstract, as attached herewith.

REMARKS

The specification has been reviewed, and clerical errors of the specification have been amended.

In regard to the amendment in paragraph 0031 of the specification, the explanation relative to S5 shown in the equation was inadvertently omitted in the original specification. However, since other symbols S1 to S4 are explained in the original specification, it is apparent that S5 means a bottom area of the heat exchange concave. Therefore, the amendment does not introduce new matter.

In paragraphs 2, 3 and 5 of the Action, claims 1-14 were rejected by Yamada et al., Mountsier et al. and Sexton et al. In view of the rejections, claims 1-14 have been cancelled, and new claims 15-28 have been filed.

An electro-static chucking mechanism for chucking an object electro-statically in claim 15 of the invention includes a stage. The stage includes a dielectric block having a chucking surface with a concave to be closed by the object for chucking thereon, gas introducing channels communicating with the concave, a chucking electrode provided in the dielectric block, a main body fixed to the dielectric block and having a cavity, and a sheet inserted between the main body and dielectric block for enhancing heat transfer therebetween. The heat transfer between the main body and the dielectric block is improved by the sheet interposed therein as stated in paragraph 0014 of the original specification.

The chucking mechanism further includes a temperature controller attached to the main body to circulate a coolant to the cavity for controlling temperature of the object, a chucking power supply connected to the chucking electrode to apply voltage thereto

to chuck the object, and a gas introduction system connected to the gas introducing channels for introducing heat-exchange gas into the concave to control temperature of the object while increasing pressure in the concave.

The chucking mechanism further includes lift pins for receiving and transferring the object. Each lift pin is disposed in each gas introducing channel so that the heat-exchange gas is introduced to the concaves only through the gas introducing channels in which the lift pins are provided. Since the heat-exchange gas is introduced to the concaves only through the gas introducing channels with the lift pins therein, the gas can be equally introduced into the concaves. Thus, the object can be treated equally.

The surface processing apparatus in claim 22 has the process chamber and the electro-static chucking mechanism as explained above.

In Yamada et al., an electrostatic chuck includes a supporting portion 8, an electrode 9 buried in the supporting portion 8, small projections 26 and circular discoidal portion 27 which are formed on an upper surface of the supporting portion 8, and gas introducing holes 42.

In the invention, the stage includes the dielectric block having the chucking surface with the concave, the main body fixed to the dielectric block and having the cavity, and the sheet inserted between the main body and dielectric block for enhancing heat transfer therebetween. In Yamada et al., the supporting portion 8 is formed of one structure, not formed of the dielectric block, the main body and the sheet interposed between for enhancing heat transfer, unlike the invention.

In the invention, also, the main body has the cavity, and the coolant is supplied to the main body by the temperature controller, in addition to the supply of the heat-exchange gas to the concave on the dielectric block contacting the object. In Yamada et al., gas is only supplied to the concaves on the surface contacting the object. Thus, the temperature controller and its system for controlling the temperature of the object or main body are not disclosed or suggested in Yamada et al.

The chucking mechanism of the invention is not disclosed or suggested in Yamada et al.

In Mountsier et al., a wafer cooling device includes a ceramic disk 52 with a gap 68 to be filled with a gas, a metallic support disk 56 disposed under the ceramic disk 52, and a metallic cooling disk 60 with a cooling water channel 106 disposed under the support disk 56. First and second layers 54, 58 are formed for thermal conductivity between the disks.

In the invention, the chucking mechanism includes lift pins for receiving and transferring the object, wherein each lift pin is disposed in each gas introducing channel so that the heat-exchange gas is introduced to the concaves only through the gas introducing channels in which the lift pins are provided. The lift pins and their arrangement of the invention are not disclosed or suggested in Mountsier et al.

In Sexton et al., an electrostatic chuck includes a chuck body 56 having through holes 46, a heat transfer body 58, and a plenum 80 situated between the chuck body 56, and the heat transfer body 58. A gas supplied to the plenum 80 for cooling the chuck body 56 is ejected through the through holes 46 to be supplied to the backside of the wafer.

In the invention, each lift pin is disposed in each gas introducing channel so that the heat-exchange gas is introduced to the concaves only through the gas introducing channels. In Sexton et al., the gas is simply supplied on the backside of the wafer, not the concaves of the dielectric block. Also, since the gas in the plenum 80 is supplied through the through holes 46, the heat exchange efficiency is not good.

As explained above, the cited references do not disclose or suggest the features of the invention. Even if the cited references are combined, the present invention is not obvious from the cited references.

Reconsideration and allowance are earnestly solicited.

A two month extension of time is hereby requested. A check in the amount of $410.00 is attached herewith for the two month extension of time.

Respectfully Submitted,

KANESAKA AND TAKEUCHI

By Manabu Kanesaka

Manabu Kanesaka
Reg. No. 31,467
Agent for Applicants

1423 Powhatan Street
Alexandria, VA 22314
(703) 519-9785

TITLE OF THE INVENTION

ELECTRO-STATIC CHUCKING MECHANISM AND SURFACE PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

[0001] The invention of this application relates to an electro-static chucking (ESC) mechanism for chucking an object electro-statically on a chucking surface. Especially, this invention relates to such an ESC mechanism having heat-exchange function to the object as one that is incorporated into a surface processing apparatus.

[0002] The electro-static chucking technique is widely used for automatically holding location of an object without damage. Especially, various kinds of surface processing apparatuses utilize the electro-static chucking technique to hold a substrate as the object at a certain position. The electro-static chucking mechanism usually comprises ~~a~~ any ESC stage on which the object is chucked, and a chucking power source to apply voltage to the ESC stage for chucking the object. The ESC stage is roughly composed of a main body, a dielectric block fixed with the main body, and a couple of chucking electrodes provided within the dielectric block. Static electricity is induced on the dielectric block by voltage applied to the chucking electrodes, thereby

chucking the object.

[0003] Such the electro-static chucking mechanism sometimes has heat-exchange function between the object and the ESC stage. Surface processing apparatuses, for example, often employ the structure that a heater is provided within the ESC stage, or coolant is circulated through the ESC stage, for controlling temperature of the object in a specific range during the process. For the temperature control of the object, the heater is usually negative feedback controlled. The coolant is maintained at a specific low temperature.

[0004] In such the temperature control, there arises the problem that accuracy or efficiency of the temperature control decreases, when heat exchange between the ESC stage and the object is insufficient. Particularly in the surface processing apparatuses, the object is sometimes processed under vacuum environment within a process chamber. Minute gaps exist between the ESC stage and the object because those interfaces are not completely flat. The heat exchange through the gaps is very poor because those are at vacuum pressure. Therefore, the heat exchange efficiency between the ESC stage and the object is lower than the case those are at the atmosphere.

[0005] To solve this problem, a kind of surface processing apparatuses employs the structure that heat-exchange gas is

introduced between the ESC stage and the object. The surface of the ESC stage, which is the chucking surface, has a shallow concave. Here, "chucking surface" in this specification means the surface of the side at which the object is chucked. Not always the object is chucked on the whole area of the chucking surface. The opening of the concave is shut with the chucked object. The ESC stage has a gas-introduction channel, through which the heat-exchange gas is introduced into the concave.

[0006] In the above-described ESC mechanism, depth of the concave is preferably small. In the concave, the heat-exchange gas molecules need to travel between the bottom of the concave and the object for the heat exchange. If the concave is deeper, the gas molecules must travel longer, making possibility of dispersion by mutual collision higher. As a result, the heat-exchange efficiency decreases.

[0007] On the other hand, the heat-exchange gas is introduced into the concave from the outlet of the gas-introduction channel, which is provided on the bottom of the concave. The heat-exchange gas diffuses along directions parallel to the chucking surface, filling the concave. To fill the concave with the heat-exchange gas uniformly, conductance of the heat-exchange gas along the diffusion directions needs to be high enough. However, when the concave is shallower, the conductance of the heat-exchange gas

may decrease. Therefore, the heat-exchange gas cannot diffuse uniformly, resulting in that pressure in the concave becomes out of uniform along the directions parallel to the chucking surface. This leads to temperature non-uniformity of of the object along those directions. This often means, in the surface processing apparatuses, that which the process of the object becomes out of uniform.

SUMMARY OF THE INVENTION

[0008] Object of this invention is to solve the problems described above.

[0009] To accomplish this object, the invention presents an ESC mechanism for chucking an object electro-statically on a chucking surface, comprising a stage having a dielectric block of which surface is the chucking surface, and a chucking electrode provided in the dielectric block. A temperature controller is provided on the stage for controlling temperature of the object. A chucking power source to apply voltage to the chucking electrode is provided so that the object is chucked. The chucking surface has concaves of which openings are shut by the chucked object. A heat-exchange gas introduction system that introduces heat-exchange gas into the concaves is provided. The concaves include a heat-exchange concave for promoting heat-exchange

between the stage and the object under increased pressure, and a gas-diffusion concave for making the introduced gas diffuse to the heat-exchange concave. The gas-diffusion concave is deeper than the heat-exchange concave.

[0010] Further to accomplish the object, the invention also presents a surface processing apparatus, comprising a process chamber in which a surface of an object is processed, and the electro-static chucking mechanism of the same composition.

BRIEF DESCRIPTION OF DRAWINGS

[0011] Fig.~~2~~1 is a front cross-sectional view schematically showing an electro-static mechanism of the embodiment of the invention.

Fig.2 is a plan~~e~~ view of the ESC stage 2 shown in Fig.1.

Fig.3 is a side cross-sectional view taken along line 3-3 on A-A shown in Fig.2, explaining the concave-convex configuration on the chucking surface of the ESC stage 2.

Fig.4 is a side cross-sectional view taken along line 4-4 on B-B shown in Fig.2, explaining the concave-convex configuration on the chucking surface of the ESC stage 2.

Fig.5 is a side cross-sectional view taken along line 5-5 on C-C shown in Fig.2, explaining the concave-convex configuration on the chucking surface of the ESC stage 2.

Fig.6 is a schematic plan~~e~~ cross-sectional view explaining the configuration of the cooling cavity 200 within the main body 21.

Fig.7 is a schematic front cross-sectional view of a surface processing apparatus of the embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] The preferred embodiments of the invention are described as follows.

[0013] The ESC mechanism shown in Fig.1 comprises an ESC stage 2 of which surface is the chucking surface, and a chucking power source 3 to apply voltage so that the object can be chucked. The ESC stage 2 is roughly composed of a main body 21, a dielectric block 22 fixed with the main body 21, and a couple of chucking electrodes 23,23 provided in the dielectric block 22.

[0014] The main body is made of metal such as stainless steel or aluminum. The dielectric block is made of dielectric such as alumina. A sheet 29 made of eutectic alloy including indium, or low-melting-point metal or alloy is inserted between the main 21 body 21 and the dielectric block 22. The sheet 29 is to enhance heat transfer by filling the gap between the main body 21 and the dielectric block 22. The chucking electrodes 23,23 are the boards provided in parallel to the chucking surface. It is

preferable that configuration and arrangement of the chucking electrodes 23,23 are symmetrically coaxial with the center of the ESC stage 2.

[0015] What much characterizes this embodiment is in configuration of the chucking surface of the ESC stage 2. This point is described using Fig.1 to Fig.5 as follows. Though the chucking surface of the ESC stage 2 appears flat in Fig.1, actually it has concave-convex configuration. Fig.2 shows a plane view of this configuration. Fig.3, Fig.4 and Fig.5 show a side cross-sectional configuration of the chucking surface in detail. Fig.3 is the cross-section on 3-3 A-A shown in Fig.2. Fig.4 is the cross-section on 4-4 B-B shown in Fig.2. Fig.5 is the cross-section on 5-5 C-C shown in Fig.2. The upper surface of the dielectric block 22 corresponds to the chucking surface. As shown in Fig.1, the dielectric block 22 protrudes upward as a whole. The object 9 is chucked on the top of the protrusion. Therefore, the top surface of the protrusion is the chucking surface.

[0016] As shown in Fig.2, the plane view of the chucking surface is circular as a whole. The object 9 is circular as well, having nearly the same radius as the chucking surface. The dielectric block 22 has a circumferential convex 24 along the outline of the circular chucking surface. The convex 24 is hereinafter called "marginal convex". Inside the marginal convex

24, many small column-shaped convexes 25 are formed. Each of the convexes 25 is hereinafter simply called "column convex". As shown in Fig.3, the top surface of the marginal convex 24 and the top surface of each column convex 25 are the same in height. When chucked, the object 9 is in contact with both of the top surfaces. Therefore, in this embodiment, the chucking surface is composed of the top surface of the marginal convex 24 and the top surface of each column convex 25. When the object 9 is chucked, the concave 26 formed of the marginal convex 24 and the column convexes 25 is shut by the object 9.

[0017] The concave 26 formed of the marginal convex 24 and the column convexes 25 is the one for promoting the heat exchange between the ESC stage 2 and the object 9. This concave 26 is hereinafter called "heat-exchange concave". What characterizes this embodiment is that another concave 27 is provided in addition to the heat-exchange concave 26 so that the heat-exchange gas can diffuse efficiently to be introduced uniformly into the heat-exchange concave 26. The concave 27 is hereinafter called "gas-diffusion concave".

[0018] As shown in Fig.2, the gas-diffusion concave 27 is composed of spoke-like-shaped trenches 271 radiate from the center of the ESC stage 2, and trenches 272 which are circumferential and coaxial with the ESC stage 2. Each trench

271 is hereinafter called "radiate part", and each trench 272 is hereinafter called "circumferential part". The most outer circumferential part 272 is provided just inside the marginal convex 24.

[0019] As shown Fig.3 to Fig.5, the gas-diffusion concave 27 is deeper than the heat-exchange concave 26. A gas-introduction channel 20 is provided at the position where its outlet is at the bottom of the gas-diffusion concave 27. The gas-introduction channel 20 is lengthened perpendicularly to the chucking surface. In this embodiment, the gas-introduction channel is split into four, having four outlets. As shown in Fig.2, the four outlets are located at every 90 degrees on the second outer circumferential part 272. As understood from Fig.2 and Fig.4, the diameter of the outlet of the gas-introduction channel is a little larger than the width of the gas-diffusion concave 27.

[0020] As shown in Fig.1, the ESC mechanism comprises a heat-exchange gas introduction system 4. The heat-exchange gas introduction system 4 is composed of a gas-introduction pipe 41 connected with the inlet of the gas-introduction channel 20, a gas bomb (not shown) connected with the gas-introduction pipe41, a valve 42, a mass-flow controller (not shown) and a filter (not shown) provided on the gas-introduction pipe 41, and other components. As the heat-exchange gas, helium is adopted in this

efficiently. This is why temperature of the object 9 can be maintained highly uniform without reducing the heat-exchange efficiency.

[0027] Next, using Fig.3 and Fig.4, sizes of the heat-exchange concave 26 and the gas-diffusion concave 27 are described. The height h of the marginal convex 24 and the column convex 25 is preferably about 1 to 20 $\mu$m. When the height h is over 20 $\mu$m, the heat-exchange gas molecules need to travel longer distance for the heat exchange as described, reducing the heat-exchange efficiency. When the height h is below 1 $\mu$m, conductance in the heat-exchange concave 26 decreases much, making temperature of the object 9 out of uniform. Concretely, pressure in the heat-exchange concave 26 is higher at a region near the gas-diffusion concave 27, and lower at a region far from the gas-diffusion concave 27 because of shortage of the gas molecules. As a result, temperature of the object 9 becomes out of uniform as well.

[0028] Prudent consideration is necessary for amount area of the top surfaces of the marginal convex 24 and the column convexes 25 with respect to obtaining sufficient chucking force. Area of the object 9 in contact with the ESC stage 2 when chucked is hereinafter called "contact area". The whole surface area of the object 9 facing to the ESC stage 2 is hereinafter called

"whole facing area". The ratio of the contact area to the facing area is hereinafter called "area ratio". Generally speaking, the area ratio is preferably 3 to 20 %. In this embodiment, when the top surface area of the marginal convex 24 is S1, the top surface area of each column convex is S2, the whole facing area is S3, and the number of the column convexes 25 is n, then the area ratio R, which is

$$R=\{(S1+S2\cdot n)/S3\}\cdot 100,$$

would be preferably 3 to 20 %.

[0029] If the area ratio R is small, the whole chucking force becomes week because the surface area on which charges are induced is reduced. If the area ratio is below 3% in case that pressure in the heat-exchange concave 26 is increased for the good heat-exchange, it is required to chuck the object 9 with very high voltage, which is unpractical and difficult. On the other hand, if the area ratio R is increased over 20%, the heat-exchange concave 26 is made too small, losing the effect of the heat-exchange efficiency improvement by the high-pressure heat-exchange concave 26.

[0030] Size of the gas-diffusion concave 27 needs prudential consideration as well with respect to obtaining the sufficient heat-exchange efficiency. If size of the gas-diffusion concave 27 is enlarged much, the sufficient heat-exchange cannot be

obtained, because it is the space to enhance the gas-diffusion efficiency, sacrificing the heat-exchange efficiency. With this respect, when area of the gas-diffusion concave 27 along the chucking surface is S4, which is hereinafter simply called "cross-sectional area", S4 is preferably 30% or less against the whole area of the chucking surface, which corresponds to the area S3 of the bottom surface of the object 9. The cross-sectional area S4 is amount of eight radiate parts 271 and three circumferential parts 272.

[0031] Contrarily, if ~~the~~ the cross-sectional area S4 is made too small, it is impossible to obtain the effect of the gas-introduction uniformity by increasing the conductance. Generally, conductance of gas is proportional to area of cross section perpendicular to diffusion direction. In this embodiment, the smaller cross-sectional area S4 means that width of the gas-diffusion path is made narrow, resulting in that the conductance is reduced. Considering this point, the cross-sectional area S4 is preferably 5% or more against the whole area of the chucking surface. If S4 is over 30% against the whole area of the chucking surface, the heat-exchange efficiency may decrease too much, because it means the area of the heat-exchange concave 26 is made too small relatively. Therefore, S4 is preferably 30% or less against the whole area

of the chucking surface. t The whole area S of the chucking surface is; when S5 is a bottom area of the heat-exchange concave 26,

$$S=S1+S2 \cdot n+S4+S5=S3$$

[0032] Depth of the gas-diffusion concave 27, which is designated by "d" in Fig.3, is preferably 50 to 1000 $\mu$m. If the depth d is below 50 $\mu$m, the effect of the temperature uniformity is not obtained sufficiently, because the conductance in the gas-diffusion concave 27 can not be made higher enough than the heat-exchange concave 26. If the depth d is over 1000 $\mu$m, the conductance may increase excessively. Under the excessively high conductance, it is difficult to make pressure in the heat-exchange concave 26 high enough, bringing the problem that the heat-exchange efficiency is not improved sufficiently.

[0033] In the described operation of the ESC mechanism, the heat-exchange gas is preferably confined within the concaves 26,27. If the heat-exchange gas is not confined, it means that the object 9 floats up from the chucking surface by pressure of the heat-exchange gas. If such ~~the float-up~~ takes place, chuck of the object 9 becomes unstable. Additionally, the heat-exchange efficiency is made worse because heat contact of the ESC stage 2 and the object 9 becomes insufficient. Therefore, it is preferable to introduce the heat exchange gas to a point! as far as it does not leak out of the concaves 26,27, or to control pressure of

the heat-exchange gas so that the gas leak can be limited within bringing no matter. without trouble

[0034] Next, the embodiment of the surface processing apparatus of the invention is described using Fig.7. Fig.7 is a schematic front cross-sectional view of a surface processing apparatus of the embodiment of the invention. This embodiment of the surface processing apparatus comprises the above-described ESC mechanism. Though the above described ESC mechanism can be utilized for various kinds of surface processing apparatuses, an etching apparatus is adopted as an example in the following description. Therefore, the apparatus shown in Fig.7 is the etching apparatus.

[0035] Concretely, the apparatus shown in Fig.7 is roughly composed of a process chamber 1 comprising a pumping system 11 and a process-gas introduction system 12, the ESC mechanism holding the object 9 at a position in the process chamber 1, and a power supply system 6 for generating plasma in the process chamber 1, thereby etching the object 9.

[0036] The process chamber 1 is the airtight vacuum chamber, with which a load-lock chamber (not shown) is connected interposing a gate valve (not shown). The pumping system 11 can pump the process chamber 1 down to a specific vacuum pressure by a turbo-molecular pump or diffusion pump. The process-gas

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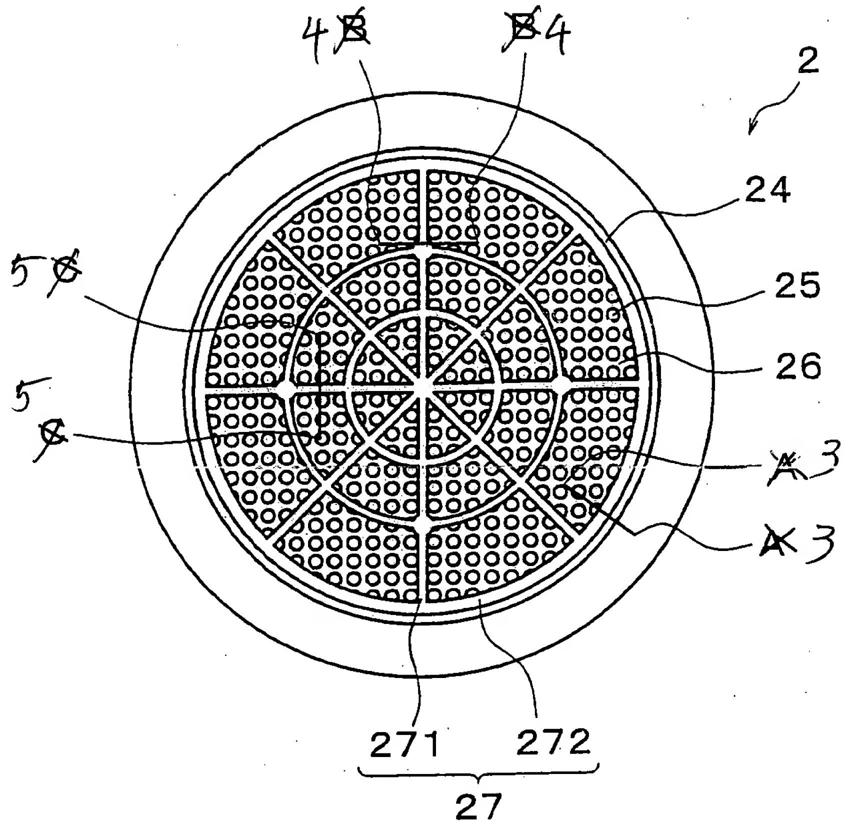


Fig. 2

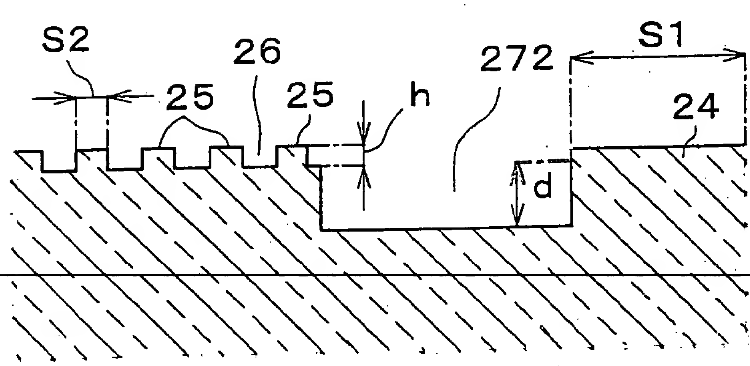


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Fig. 3